ENERGY-10: The Making of a Design Tool

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SOLAR 97

22nd National Passive Solar Conference

American Solar Energy Society

April 25-30
Washington, D.C.

Paper #011

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ABSTRACT

The *ENERGY-10* computer program, released in June 1996, is a design tool, distinct from other energy-evaluation programs. Energy performance simulation, based on an hourly time step through a year of typical data, is an essential part of the process; however, *ENERGY-10* goes far beyond this to facilitate the integration of energy efficiency into the design process of a building. *ENERGY-10* incorporates time-saving features, *AutoBuild*, *APPLY*, *RANK*, and *KEEP*, and produces a rich graphical output. The program was described in a paper, "The *ENERGY-10* Design Tool Computer Program," presented at the American Solar Energy Society (ASES) conference, Solar 95, in Minneapolis, MN, and in a *Solar Today* article, "*ENERGY-10:* Saving Energy by Design," by Rick Clyne (May/June 1996, pp 24-27).

This paper describes the origins of *ENERGY-10.* It evaluates how well our approach has succeeded and describes proposed remedies to shortcomings. The purpose is fourfold—to expand on the rationale for the design of the program, to describe enhancements that are planned for future releases of the program, to evaluate user feedback, and to discuss *ENERGY-10* as a tool for getting new strategies into the marketplace.

1. THE REEMERGENCE OF DAYLIGHTING

The use of natural light in buildings was a well-established tradition prior to about 1920. The advent of the fluorescent light bulb; modern heating, cooling and air-conditioning equipment; and the modern movement in architecture quickly led to a near-total dependence on artificial lighting. The design of windows for nonresidential buildings made them nearly useless for lighting the interior. The art and science of daylighting floundered for lack of interest.

The interest in daylighting was rekindled with the surge of interest in passive solar buildings which started at the first passive solar conference in Albuquerque, NM, in 1976, and crested at the fifth conference in Amherst, MA, in 1980. Hundreds of designers learned how to do passive solar design, many by trial and error, and it was estimated that 200,000 homes and 15,000 nonresidential passive solar buildings were in place by 1985 (Renewable Energy Institute, 1986). A major interest in daylighting developed, starting at about the sixth passive conference in Portland, OR, in 1981, which rapidly led to a recognition that daylighting is the most significant passive solar strategy for non-residential buildings. The multiple energy-saving synergy between savings in electricity for artificial lighting, reductions in cooling loads, and downsizing of installed heating, ventilating, and air-conditioning (HVAC) equipment was widely touted. Architects, who were hostile to the mechanical character of active solar but were mildly disposed toward passive solar heating, became excited by daylighting opportunities. They emphasized five principal reasons for daylighting (more or less in order of importance):

1. The aesthetic benefits of natural light
2. the improved productivity of workers, performance of students, or well-being of occupants
3. the reductions in peak electric use leading to reduced utility demand charges
4. the reductions in peak HVAC loads, leading to downsizing of installed equipment and associated

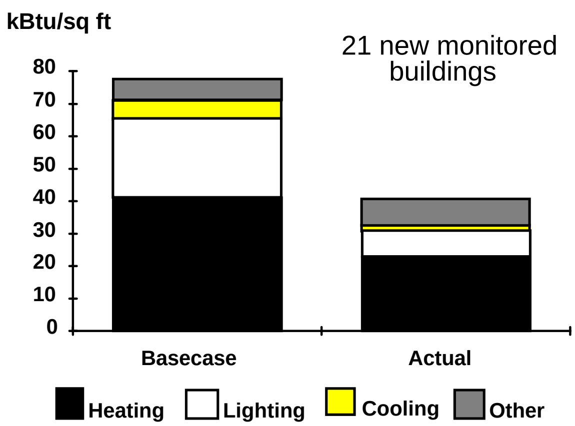
* Chairman of the Passive Solar Industries Council (PSIC)

reductions in installed cost (which often compensates for the increased cost of the daylighting), and
5. the energy-savings.

Together, the reasons form a compelling case for daylighting. Two international daylighting conferences were organized (1983 and 1987) with strongly architectural themes. Daylighting began to make a comeback as an architectural design driver, but quite often was not executed to achieve the last three benefits listed above.

2. INTEGRATED DESIGN

A landmark program of the U.S. Department of Energy (DOE), the Passive Solar Commercial Demonstration Program, highlighted and publicized the need and benefits of taking a whole-building, integrated design approach. Monitored results clearly demonstrated that heating, cooling, and lighting loads could all be reduced significantly through building design without increasing initial cost (Burt, Hill, Kosar, Rittleman, 1983). Nonetheless, the buildings were not replicated and mainstream architectural practice largely ignored these opportunities.



The buildings use half the energy of conventional non-daylit buildings, cost no more, or sometimes less, to build and provide a far better indoor environment. Why are they not being replicated? The reasons are numerous and complex. Clearly, energy savings are not a sufficient reason in an era of cheap and plentiful energy…initial cost is more important…government is ambivalent...reduced operating costs often do not benefit the first owner…it is generally not understood or believed that occupant productivity will increase...aesthetics do not necessarily impact the bottom line… etc., etc.
Integrated design requires a whole-building approach fully appreciated by only a handful of designers. The architectural profession remains remarkably focused on stylistic issues. Building owners are largely unaware of the opportunities available. Without motivation and with several disincentives in place, integrated design almost died out before it was born.

Interest in whole-building design, or integrated design, is returning in the 1990s, driven by a healthy concern for the environment. It is probably stronger outside the United States than within, especially in Europe. Designers who learned the trade 15 years earlier have suddenly found a demand for their services. The stage is set for *ENERGY-10*.

3. DESIGN COSTS

The DOE Passive Solar Commercial Demonstration Program showed that although energy-efficient buildings did not, on average, cost any more to construct, they did cost more to design.* Although this added cost might be a small part of the overall cost of the building, it is a significant part of the design budget. There is no leeway for doing energy analysis in this budget. This is a major impediment to energy-efficient design and was one of the contributing factors for integrated design not having made larger inroads 15 years ago.

The high cost of integrated design is due to two main factors:

(1) It is time consuming. Proper evaluation of options is a complex process involving many trade-offs between issues. Accounting for all the important effects requires a detailed hour-by-hour simulation. For example, the process should include simultaneous evaluation of daylighting, the thermal effects of the reduced lighting loads, and the resulting HVAC and time-of-day effects on demand charges. Without this evaluation, the interactions between heating, cooling, and daylighting cannot be understood.

(2) Energy efficiency must be included in the design from the start, beginning in predesign and particularly during the preliminary design phase (schematic design). Traditional detailed evaluation tools, such as the large programs available for thermal and daylighting simulation, are not suitable. Because existing tools have been so difficult to use, they have been employed late in the design process—when it is too late to affect the result.

To overcome these impediments, we set a difficult target for *ENERGY-10*: All of the energy calculations required for a small building, say, in the range of 10,000 square feet (about 1000 square meters), should be accomplished in half a day.

* The U.S. DOE paid for the added design and monitoring costs for the 21 buildings in the Passive Solar Commercial Demonstration Program.

Otherwise, it won't be done. This compares to at least 2 weeks time typically required using available tools.

4. THE PASSIVE SOLAR INDUSTRIES COUNCIL TASK GROUP

A Task Group, chaired by Adrian Tuluca from Steven Winter Associates, was set up to help guide the development of a new design tool. This task group brought together representatives of the major interested parties—architects, professional engineers, utilities, component and equipment suppliers—to advise on the principal directions. The first task group meeting was held in November 1990, and the meetings have continued through to the present.

The task group decided to model the project on the very successful residential guidelines project developed in concert by the National Renewable Energy Laboratory (NREL) and the Passive Solar Industries Council (PSIC) with DOE funding. The residential project is called *Passive Solar Design Strategies: Guidelines for Home Builders.* It combines a guidelines book and a computer program in one package. Each book is applicable to a small climate region. Dissemination is largely to home builders, consultants, and homeowners through one-day workshops. To date, about 200 different versions of the guidelines have been published and 70 workshops presented.

The focus of the new, nonresidential, project was to be on smaller buildings—generally less than 10,000 square feet. This is because (1) smaller buildings have been neglected, (2) their performance is less dominated by internal heat gains, and (3) there are more opportunities for passive strategies because of their larger surface to volume ratio. These buildings comprise 76% of all nonresidential buildings in the United States, 22% of the total floor area, and use 28% of the total energy.

Clearly, the different character of nonresidential buildings required some changes in the residential approach. The computer program would need to be much more complex but should not be much more difficult to run, and there should be less need to target the guidelines locally. The primary target audience should be building designers, architects, HVAC engineers, utility officials, and architecture and engineering students and professors. Workshops should be two days with computer hands-on training.

The team decided to place the initial emphasis on the front end and the back end of the computer program—the user interface and the output graphics—because these areas are neglected in other tools. The required simulation engines were available and only required adaptation to make them suitable for use.

ENERGY-10 and its associated guidelines book were designed to solve the dilemma outlined above. The user sees the impact of design changes on potential savings in total energy and operating costs from the beginning. The program enables the user to select passive solar, daylighting, and other features to create a design that inherently requires minimum backup. Selecting highly efficient heating and cooling equipment completes the process, leading to a building that minimizes annual energy, annual operating cost, or life-cycle cost.

PSIC developed the guidelines book, called *Designing Low-Energy Buildings*, and NREL developed the software, assisted in the daylighting area by the Lawrence Berkeley National Laboratory (LBNL) and in the thermal area by the Berkeley Solar Group (BSG). The name, *ENERGY-10*, was selected (somewhat arbitrarily) based on the energy analysis emphasis and on the 10,000 square foot building size limit.[*]

5. CHRONICLE

The alpha test version of *ENERGY-10* was released in 1994, the beta test version in July of 1995, and Version 1.0 was released in June 1996. A beta-test workshop was held in Minneapolis in conjunction with SOLAR 95. PSIC is responsible for dissemination and training. The first two workshops were held in Muncie, IN, and Amherst, MA. The program is available from PSIC, 1511 K St. NW, Suite 600, Washington, D.C. 20005, 202-628-7400. The first upgrade, Version 1.1, was released in February 1997 (registered users can download the modified files from the PSIC web site, http://www.psic.org).

6. *ENERGY-10* IN BRIEF

Space restrictions preclude a full description of *ENERGY-10* in this paper. The reader is referred to Balcomb and Crowder, 1995, for details.

ENERGY-10 is suitable for evaluating buildings that can be represented by one or two thermal zones, which restricts its use to residential and to smaller nonresidential buildings. At the start of a new project, the program automatically sets up two building descriptions based on only five key characteristics—information that is known in predesign. It then automates the process of both applying and ranking a variety of energy efficiency and passive solar measures.

[*] Bion Howard suggested the name.

Thermal issues are integrated with the daylighting issues in a package that gives preliminary results before the building is designed. *Designing Low-Energy Buildings* emphasizes the use of passive solar measures including daylighting, passive solar heating, and ventilation cooling as design options to be integrated with efficient equipment and shell designs.

With the automatic features of *ENERGY-10*—AutoBuild, APPLY, and RANK—the user can spend less than an hour during predesign and be well equipped to begin design, knowing which strategies should be investigated as the design proceeds. The designer can present these initial results to the client, and the two parties can agree on energy-performance goals for the building.

As the building proceeds from predesign into preliminary design (schematic design), the building description in *ENERGY-10* must be modified to represent the various schemes being considered. This is done by editing the initial *low-energy case* generated by AutoBuild. The graphical user interface in *ENERGY-10* makes this process both fast and intuitive. The APPLY and RANK features can be used at any point to evaluate global changes. Other changes, such as modifications in the building takeoffs, can be made by simply editing values, such as the area of a particular wall, in the appropriate menu. As the design proceeds, the building descriptions become more detailed and more representative of the building being designed and less like the original shoebox created by AutoBuild.

At each stage of the design, a new simulation can be performed to check progress. The results of the design evolution can be easily documented using the KEEP feature.

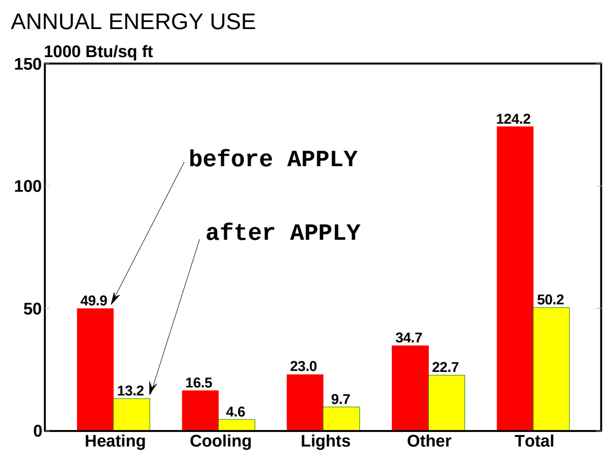
At the end of preliminary design, when others might be just thinking about doing their first simulation analysis, the user of *ENERGY-10* is nearly finished, confident that the building will be energy-efficient.

7. APPLY AND RANK

The APPLY feature of *ENERGY-10* facilitates the incorporation of any or all of the strategies included into the simulated building description. There are 10 energy-efficient strategies (EESs) to choose from in *ENERGY-10*. The user first selects any set of desired EESs from a menu and then clicks on APPLY. The program creates a new building description by modifying the *reference case* according to a prescription. For example, if the *Insulation EES* is selected, all of the walls in the building might be changed to R-19 2× 6 construction, the roof changed to R-40, and the perimeter insulated with 2 inches of foam. The user gets to specify exactly what changes will be made. The 16 EESs are listed below with the 10 that are currently automated shown in bold.

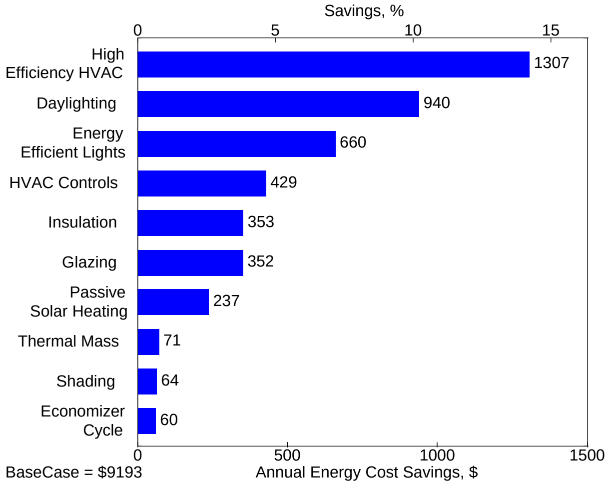
Daylighting	**Energy-Efficient Lights**
Glazing	Lighting Controls
Shading	**High-Efficiency HVAC**
Insulation	**Economizer Cycle**
Passive Solar Heating	Evaporative Cooling
Natural Ventilation	Exhaust-Air Heat Recovery
Thermal Mass	**HVAC Controls**
Air Leakage Control	Solar Water Heating

The results of an APPLY for all 10 EESs might appear as shown below for a 6500 square foot (609 square meter) bank building in Columbia, Missouri:



The RANK feature is similar to APPLY except that the EESs are applied individually rather than in combination. When the user selects a set of EESs and then clicks on RANK, the program applies the first EES, performs a simulation, saves the results, removes the EES, applies the next EES, and so forth until all the EESs have been applied and simulated. The program then ranks the results according to the desired criteria (lowest annual energy, lowest annual operating cost, lowest life-cycle cost, etc.) and displays the results. An example using the 6500 square foot bank in Columbia, MO, is shown below.

RANKING OF ENERGY-EFFICIENT STRATEGIES



8. USER FEEDBACK

PSIC maintains a hotline and compiles a list of user complaints, problems, and suggestions. A session at ASES Solar 96 in Asheville, TN, titled *ENERGY-10 Shoot-out,* provided valuable input. This feedback has been invaluable for understanding how the program is being used and how it can be modified to be more effective. Bugs have been found and places where the program is either misleading or less than intuitive have been identified.

One of the common problems is that users have a difficult time getting beyond the AutoBuild stage. Although it is extremely easy to get started with a shoe-box design because the process is so automatic, the transition to the preliminary design phase (when an actual building design must be described to the program) is awkward. The user must compute wall, roof, and window areas and enter these as numbers into the appropriate dialog boxes. Even worse, the three-dimensional coordinates of surfaces and apertures must be determined and entered to do a daylighting analysis. The user, having been led into the process smoothly, feels abandoned, cast back nearly into the era of batch-input programs. Thus *ENERGY-10* is perceived as very useful during the first, predesign, phase but less useful during later phases.

9. *ENERGY-10* ENHANCEMENTS

The PSIC Task Group has met to consider a long list of possible enhancements to *ENERGY-10*. These include fixing existing problems, ideas that were planned for Version 1.0 but not included because of time constraints, and new features. It is a long list. All potential enhancements have been thoroughly discussed, and an initial prioritization was developed accounting for the difficulty of each feature and the benefit.

Interim releases will be made, designated Version 1.1, 1.2, and 1.5. These will focus first on fixing bugs and eliminating recurring problems and then on near-term issues that were deferred under the pressure to release Version 1.0. Version 1.1, which has already been released, includes 18 fixes and improvements. Heat pumps will be included and a feature called AutoSize will be added which uses the simulation engine to determine the HVAC rated capacities required to meet thermal loads on both heating and cooling design days. At some point in the near future, the program will be distributed on CD-ROM and run only in a 32-bit environment. It is also likely that a metric-units option will be added fairly quickly.

Beyond Versions 1.x, the following features are planned, roughly in order of priority. It is likely that the first 10 will be included in Version 2.

Implement *Scheme* (see below)
Evaluate any number of zones
Implement enhanced daylighting
Implement remaining EESs
Include more HVAC systems
Report value engineering
Implement AutoComply*
Automate/graph elimination parametrics
Evaluate sunspaces
Evaluate Trombe walls
Report comfort conditions
Calculate ground heat flow
Output spreadsheet formats
Develop case studies
Report environmental impact
Implement transpired collector EES
Develop *WeatherMaker*
Evaluate horizon shading
Develop as a standards tool
Calculate inter-zonal airflow
Provide for batch runs
Provide for CAD integration
Draw shading mask
Develop STEM within E10

10. SCHEME

Scheme is a means whereby the user can enter the building description graphically rather than by numbers from

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* AutoComply would create a reference case that automatically complies with standards ASHRAE 90.1, 90.2 or CABO-MEC.

building takeoffs. This would be especially useful during the preliminary design phase of a project and addresses the input problem outlined earlier in the discussion under User Feedback. It is far less that a full-blown CAD implementation. The user would progress through several steps using a wizard. In the first steps, the building would be drawn in plan and divided into zones using the mouse. Zones would then be assigned to use categories and HVAC systems. In the next steps, windows and doors would be located, working in both plan and elevation views. Then, daylighting zones would be defined. In the final step, the graphical depiction would be converted to an *ENERGY-10* building description. *Scheme* will enable the program to handle any number of zones and complex HVAC service to various zones.

10. *ENERGY-10* AS A TOOL FOR GETTING NEW TECHNOLOGIES INTO THE MARKETPLACE

Because APPLY makes it so easy for the user to do an evaluation, *ENERGY-10* serves as an ideal mechanism to encourage the adoption of technologies into buildings. With a couple of mouse clicks, the user can globally change the building description to represent the addition of the technology and 2 or 3 minutes later he or she is inspecting the results. Technologies which might have not even been considered, because of ignorance or the difficulty of doing an evaluation, can be investigated quickly.

Technologies that are not in the mainstream but are particularly suitable for inclusion in the APPLY and RANK list include the following:

- Evaporative cooling
- Ventilation air preheat using transpired collectors
- Photovoltaics (PV)
- Desiccant cooling
- Solar water heating
- Natural cooling
- Air tightening / exhaust-air heat recovery

A major advantage of using *ENERGY-10* is that the analysis is fully integrated—all of the interactive effects are accounted for in the simulations. For example, the cooling load reductions that are a result of dimming lights in a daylit building are taken into account. In a building-integrated photovoltaics application, all the electrical loads handled by the PV system are known, including HVAC loads and artificial lighting loads, accounting for dimming of the lights in response to daylight.

Among the enhancements discussed by the PSIC task group was the inclusion of photovoltaics as an EES. Work on this is already underway under separately funding.

The benefits are (1) users who had not been thinking of PV will at least evaluate the performance, (2) users of PV who are using *ENERGY-10* for their analysis will use the program to improve the rest of the building design, and (3) the evaluations will be far more comprehensive than those made by current tools because of the realism of the hourly electrical loads. Thus, the peak-shaving benefit of a PV array will be properly determined. Because the peak is usually on a hot, clear summer afternoon, the PV system will be operating at its peak output. This can easily double the cost effectiveness of an installation in areas where electric-utility demand charges are high.

11. ACKNOWLEDGMENTS

Programming of ENERGY-10 was done by NREL, LBNL, and BSG. Funding is provided by the U.S. Department of Energy. NREL conceived the program, programmed the front end, and manages the development effort. LBL was responsible for the daylighting portions of the program, including the daylighting simulation engine, and providing technical advice on all aspects. BSG developed the thermal simulation engine and programmed the output graphics. The DOE Program Manager is Mary-Margaret Jenior, Office of Building Systems. Particular thanks go to Scott Crowder, Bruce Wilcox, Rob Hitchcock, Will Sare, Adrian Tuluca, Steven Ternoey, Greg Franta, Fred Roberts, Helen English, and Blaine Collison.

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